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Multi-Agent Simulations for Assessing Massive Sensor Deployment

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Outline

- Problem Space
- Sensor Coverage
- Sensor Deployment



Small and Mobile



Problem Space

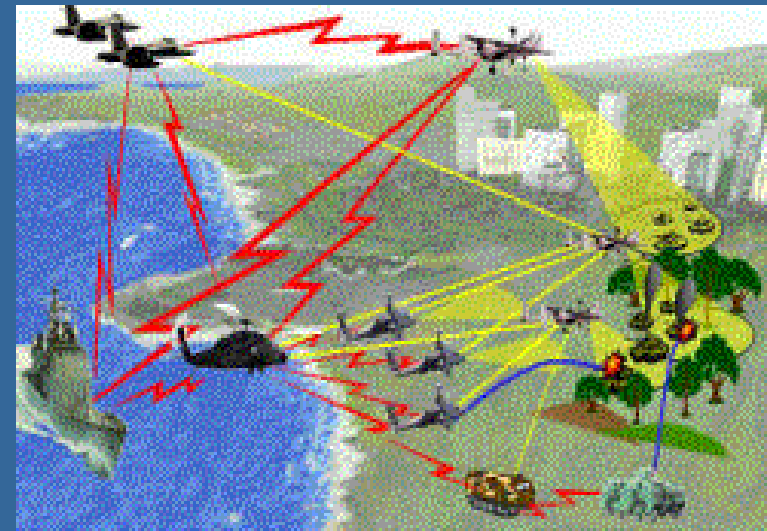
Next-generation Web and
network-centric warfare

Counterintelligence

Expeditionary sensor networks

Coverage, minimal exposure,
and cost

Efficient deployment algorithms for
autonomous sensor vehicles





Research Project

- A sensor network simulation
- Coverage and deployment issues for mobile and non-mobile sensors
- An expeditionary sensor network multi-agent simulation designed and implemented
- Novel search, coverage, and deployment algorithms implemented, tested, and compared to known methods



Coverage in Sensor Networks

We address distribution of multiple homogeneous sensors for detecting targets.

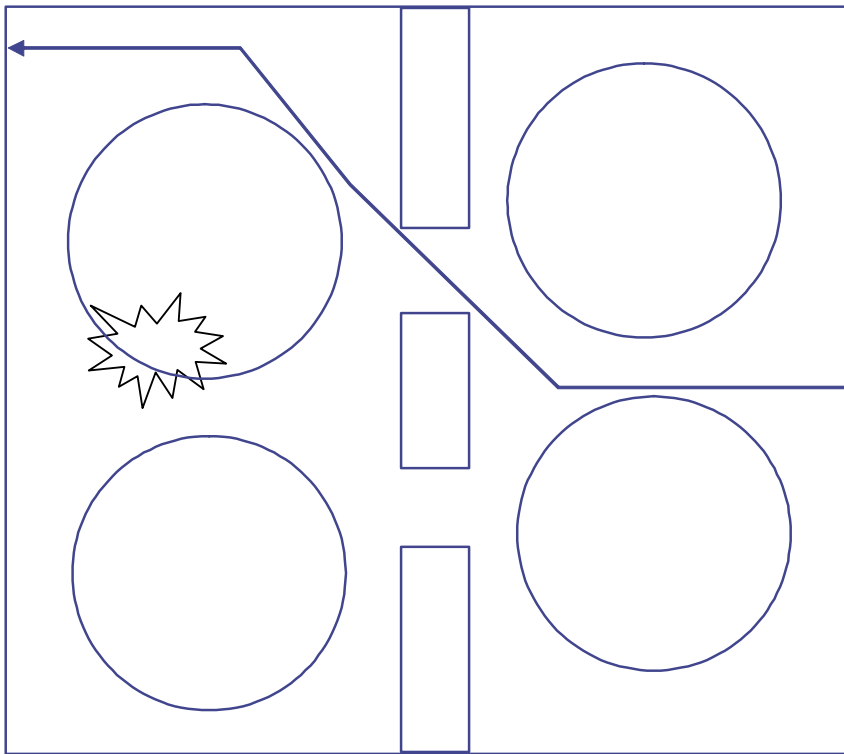
We assume a large enough number of sensors that a human operator cannot manage each.

Much literature on search in operations research.

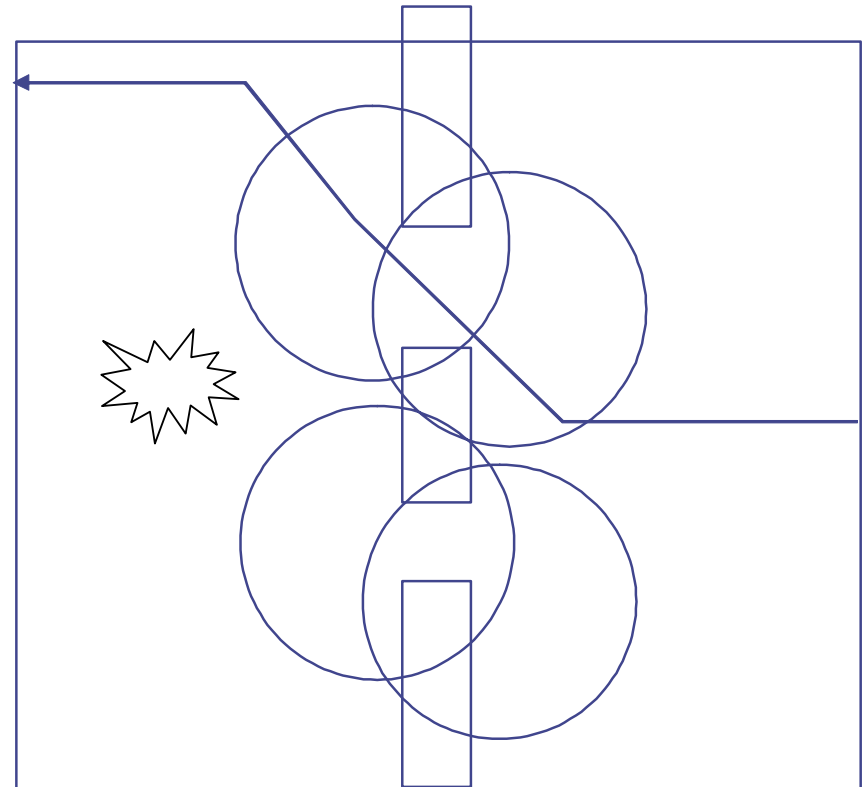
Some literature on area coverage.

Not much literature on traversal detection.

Which Deployment = Better Coverage?

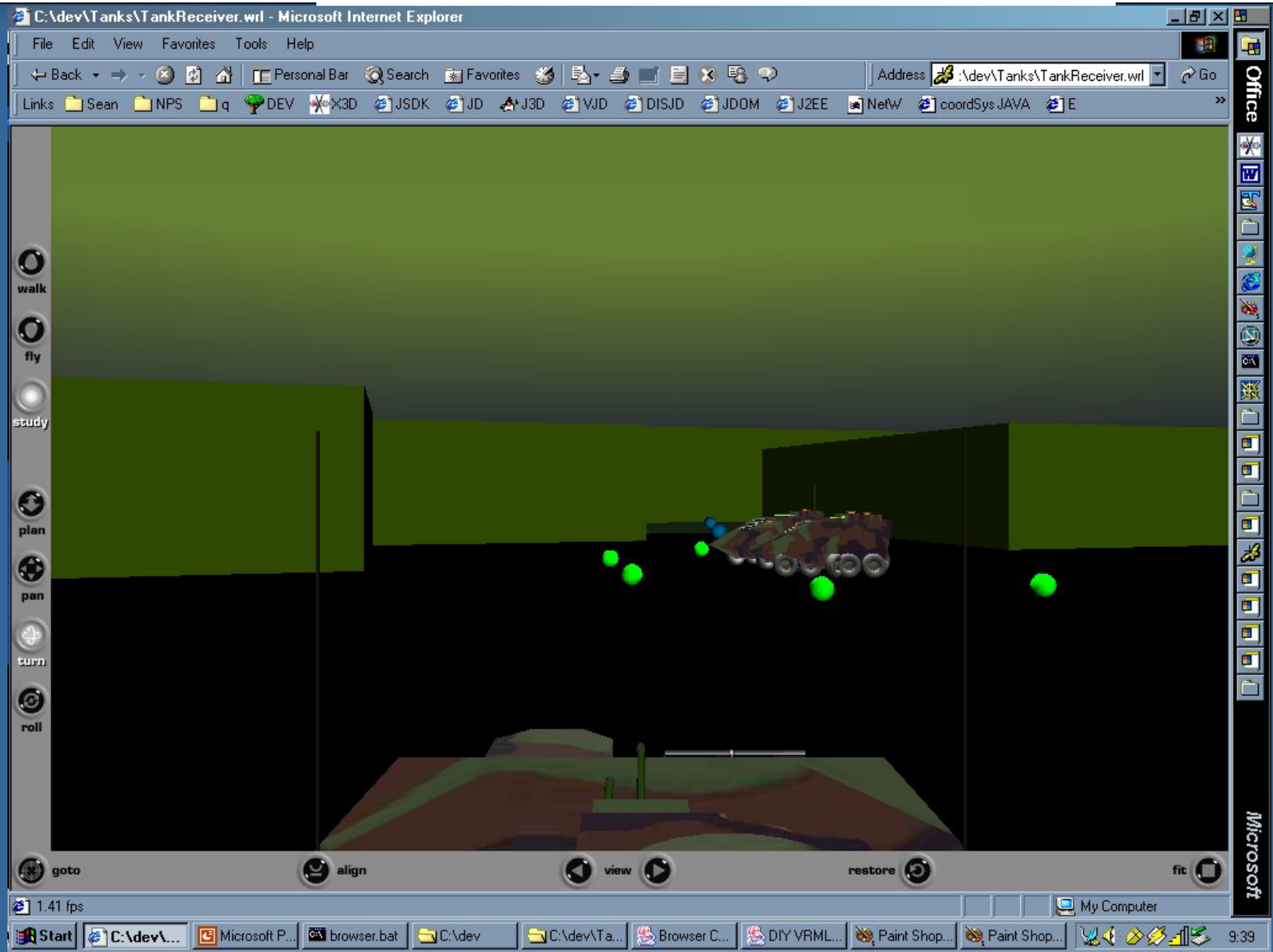


Area Coverage Deployment
(More Area Covered)



Barrier Coverage Deployment
(More Likely Traversal Detection)

Application Preview





Dimensions of sensor networks

- General sensor mechanism
 - Radial
 - Distance-directed
 - Line-of-sight
- Coverage type (sweep, area, traversal)
- Presence/absence of obstacles
- Mobility
- Localization



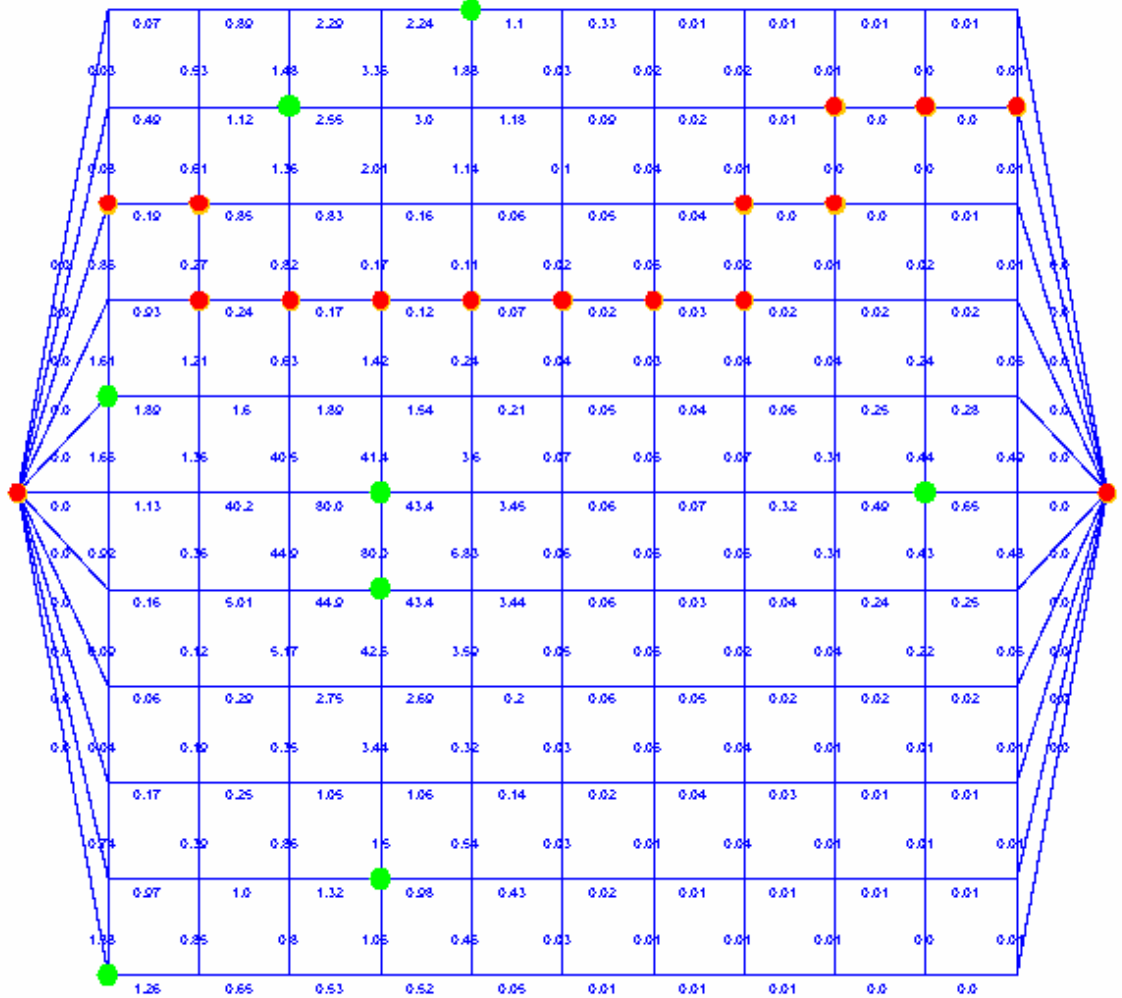
Deployment Algorithms: Constraints

- Should be efficient, de-centralized, fault-tolerant, and scaleable
- Communications
- Geographical Knowledge
- Localized Decisions



Gladiator

A grid for detecting traversal: calculate worst-case path



$$S(s, p) = \frac{\lambda}{[d(s, p)]^K}$$

Probability of detection = 87%

Placement Complexity

Consider

- N – # Sensor Nodes
- A – environment area
- D – length of grid square

Consider

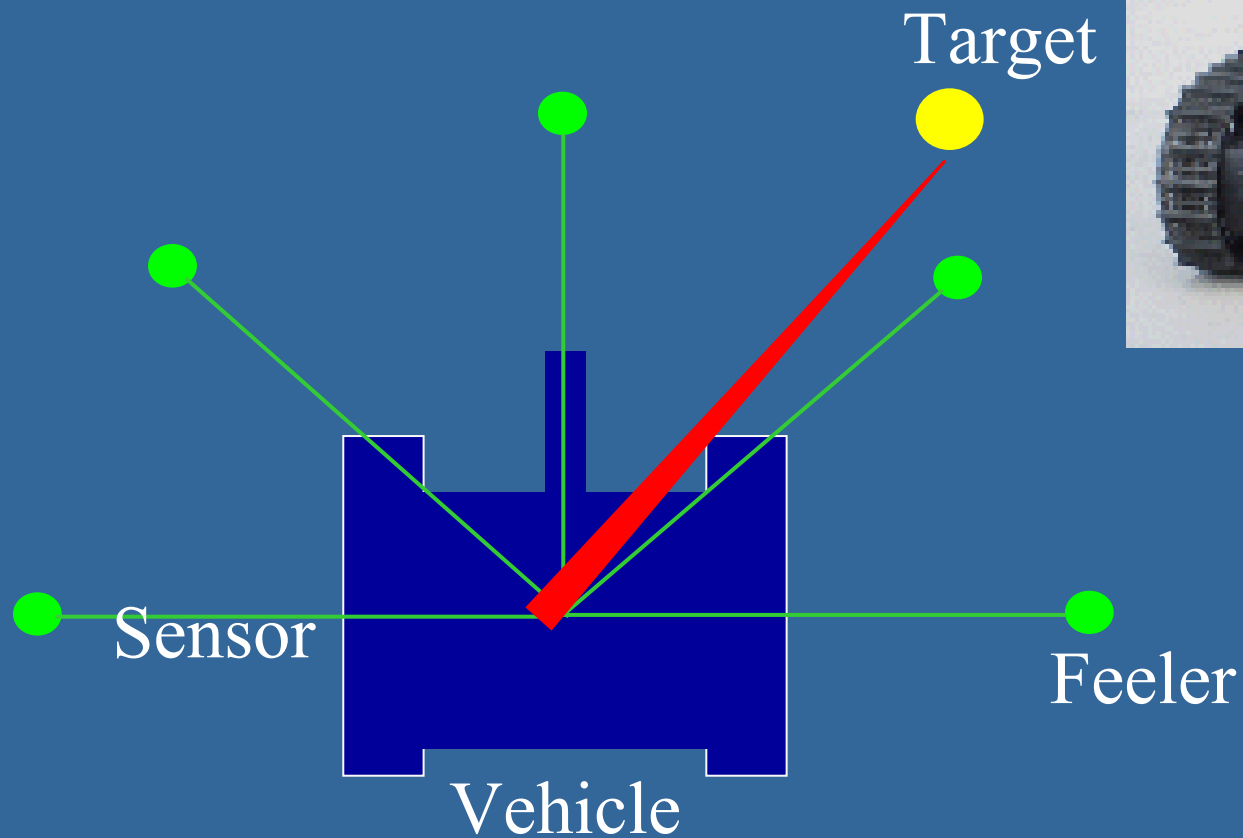
- N – 10
- A – 100 m²
- D – 10m

of Configurations

$$C = (D * A)^N$$

$$C = (10 * 100)^{10} = (10)^{20}$$

Mobile Sensor Model





Deployment Algorithms: Methods

- Global or centralized
 - Best-first, greedy, genetic, simulated annealing,
- Local or autonomous
 - Potential forces, vector field, local direction,
 - Coevolution of evasion and detection with neural networks

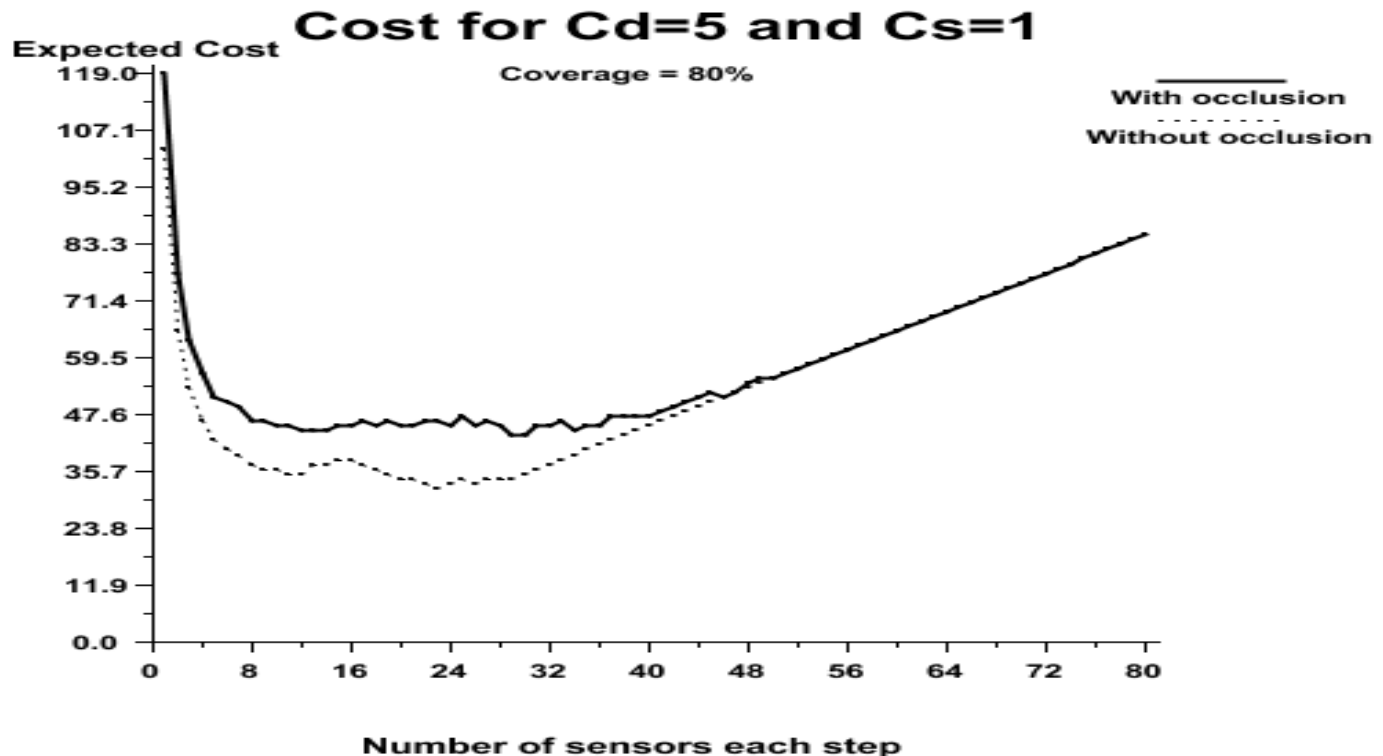


Average barrier coverage (%) with multistage random deployment

Number of sensors	2	10	15	20
Coverage %, no obstacles	4	41	64	85
Coverage %, with obstacles	6	25	39	55

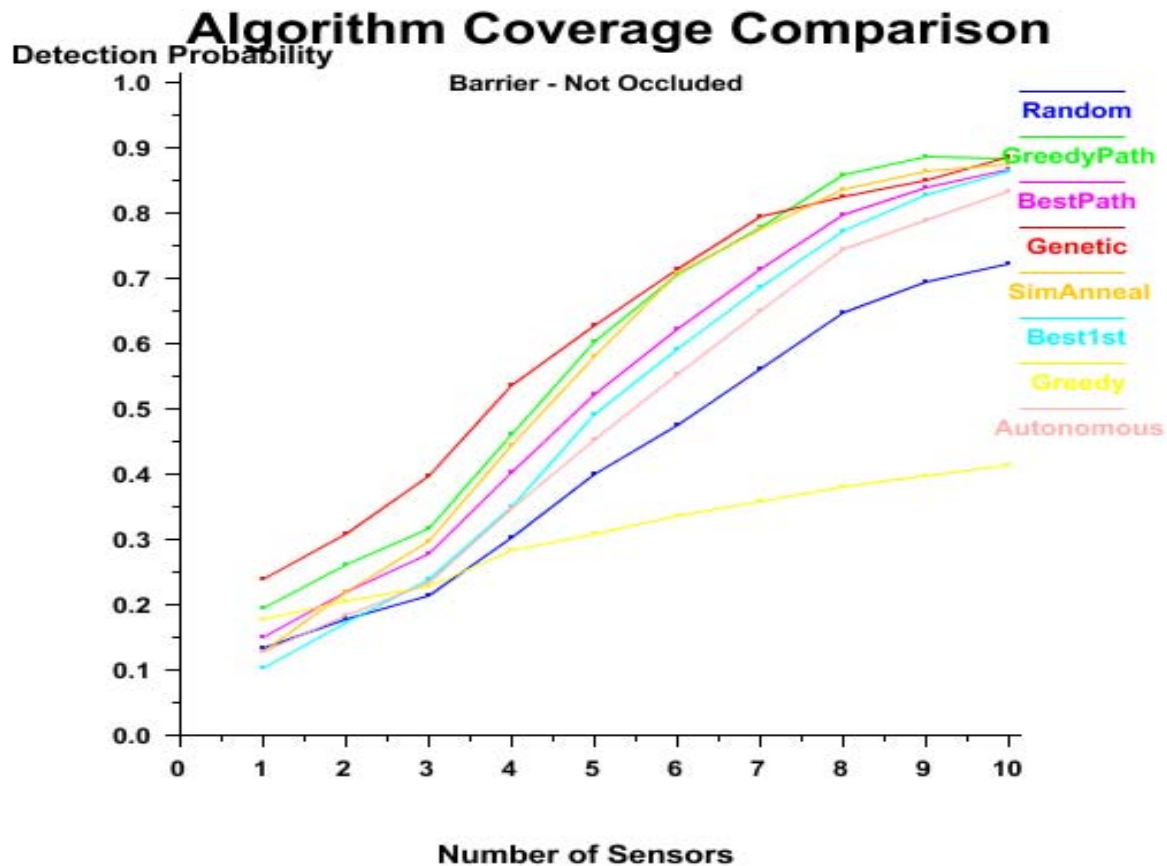


Cost of achieving 80% coverage with multistep deployment of sensors



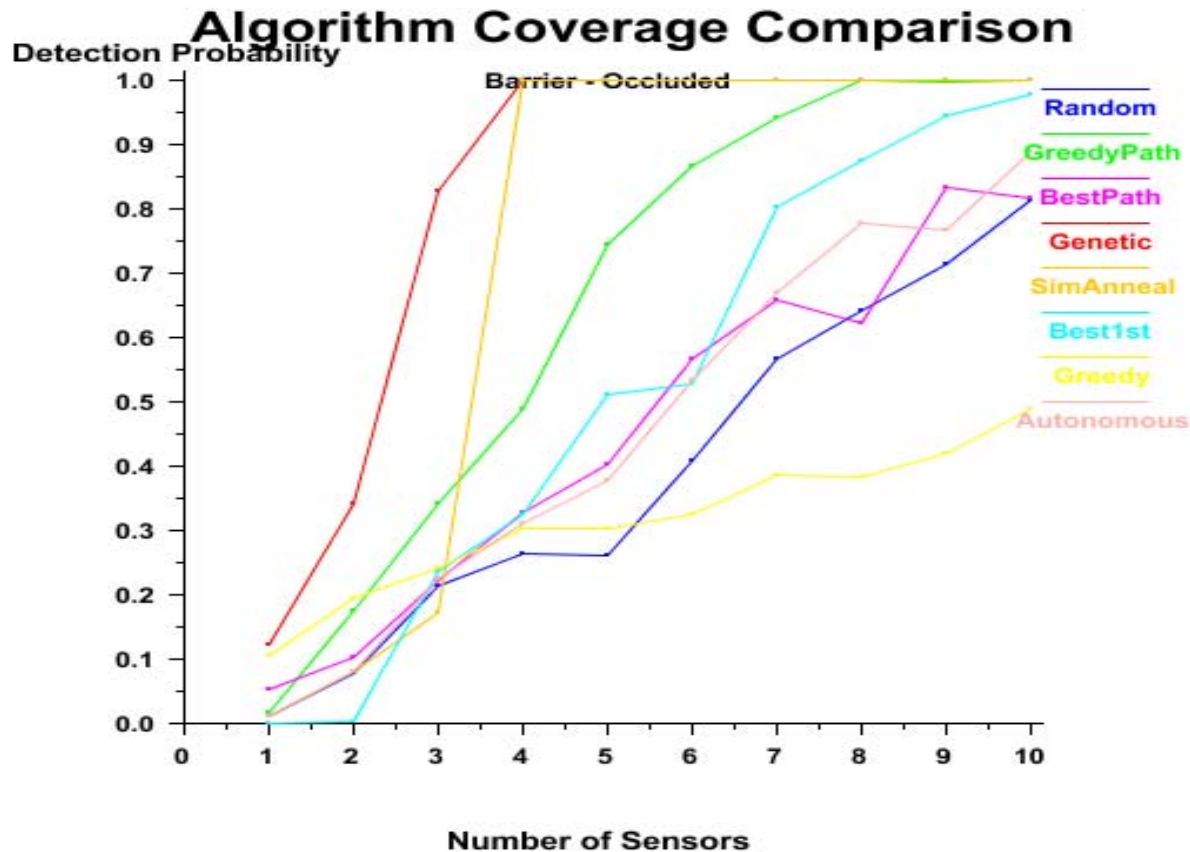


Algorithm comparison, no obstacles

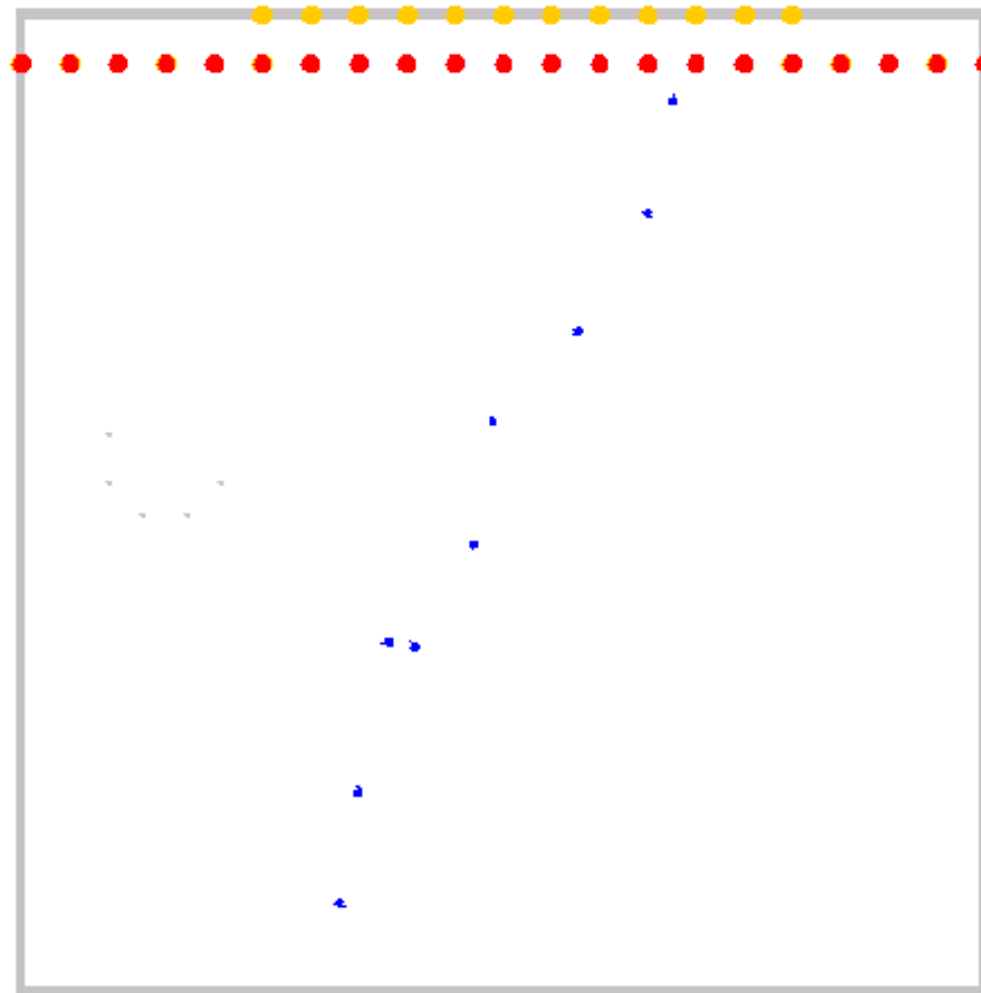




Algorithm comparison, with obstacles

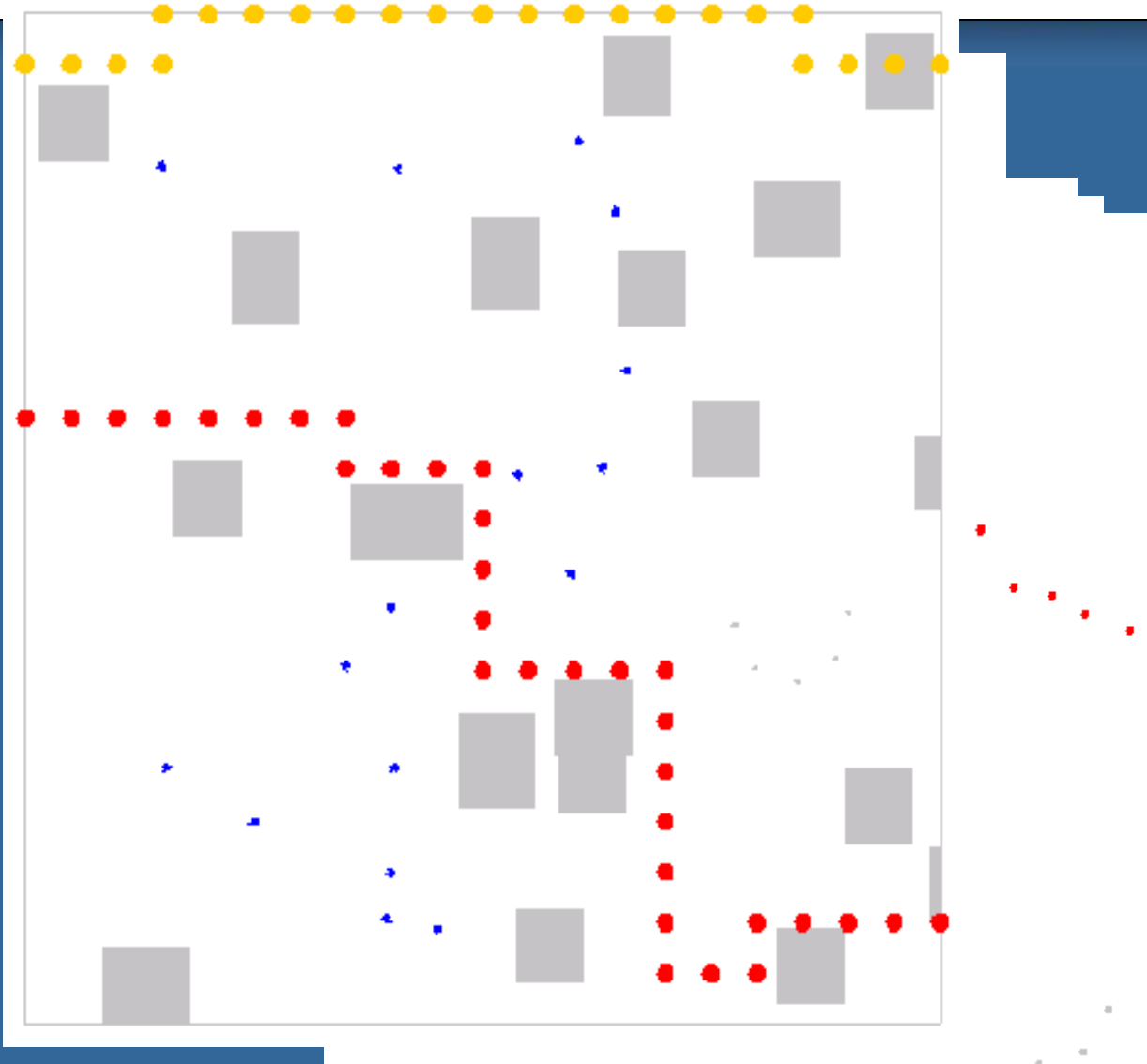


Some Pics



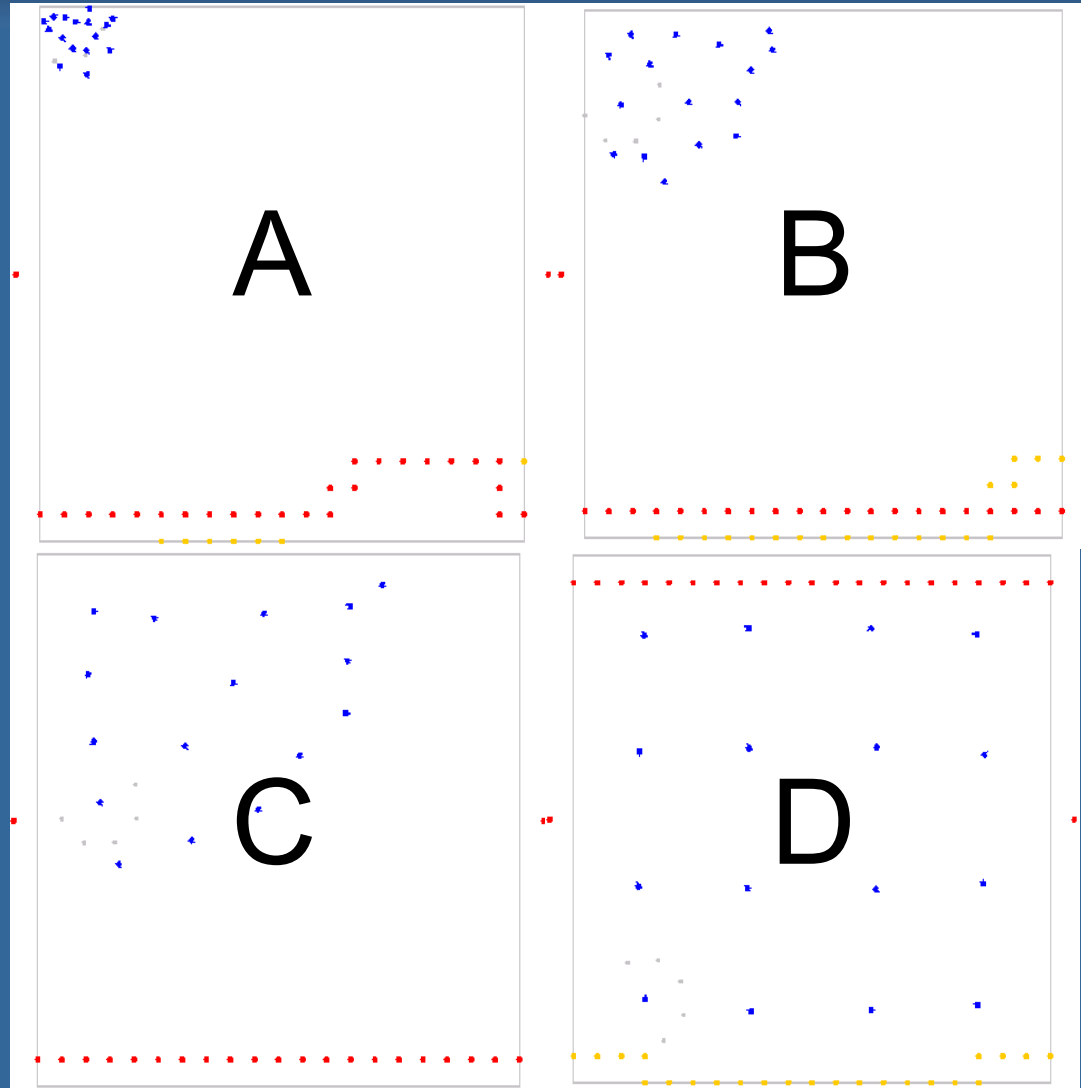
Free Detection Probability = $1 - \text{Exposure} = 0.3432$
Obstructed Detection Probability = $1 - \text{Exposure} = 0.9949$
Free Avg Detection Probability = $1 - \text{Exposure} = 0.0751$
Obstructed Avg Detection Probability = $1 - \text{Exposure} = 0.0824$

Some Pics





Some Pics





Some Pics

